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# BULLETIN

OF THE

## AMERICAN PHYSICAL SOCIETY

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PROGRAM

FOR THE

## PASADENA MEETING

AT

THE CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA

DECEMBER 20–21, 1940

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# The American Physical Society

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DECEMBER 5, 1940 Vol. 15, No. 6

# BULLETIN

OF THE

# AMERICAN PHYSICAL SOCIETY

## PASADENA MEETING, DECEMBER 20–21, 1940

THE 238th regular meeting of the American Physical Society will be held at the California Institute of Technology, Pasadena, California, in the lecture hall, room 201, of Norman Bridge Laboratory on Friday, December 20 and the morning of Saturday, December 21, 1940.

Sessions for the presentation of ten-minute contributions will be held Friday morning and afternoon, starting at 9:30 and 1:30 o'clock. The Saturday morning session will consist in part of contributed papers and in part of an illustrated talk by Dr. John A. Anderson upon problems encountered and progress achieved in the construction of the 200-inch telescope.

Members and others in attendance will be enabled to take luncheon together at the Atheneum on both days.

**Annual Meeting.** The preliminary arrangements for the Philadelphia program include a joint session on Friday afternoon, December 27, with Section B of the American Association for the Advancement of Science and the American Association of Physics Teachers, at which time addresses will be delivered by the Retiring Vice President of Section B, Ernest O. Lawrence, and by the President of the American Physical Society, John Zeleny. Arrangements are also being made for a joint session with Section E—Geology—of the American Association for the Advancement of Science.

### General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

On December 28, 1936, the Society voted that:

> No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.)

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Publications Manager, The American Institute of Physics Incorporated, 175 Fifth Avenue, New York, N. Y.

Other meetings for the current season are as follows:

239. December 26–28, 1940. Annual Meeting. Philadelphia, Pennsylvania.
240. February 21–22, 1941. Cambridge, Massachusetts.
241. May 1–3, 1941. Washington, D. C.
242. June 20–21, 1941. Providence, Rhode Island.

PAUL KIRKPATRICK,
*Local Secretary for the Pacific Coast,*
Stanford University, California.

December 5, 1940.

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## CALENDAR

All sessions will be held in Room 201, Norman Bridge Laboratory

Friday morning, December 20, 1940

9:30 o'clock: Contributed papers, 1–11.

Friday afternoon, December 20, 1940

1:30 o'clock: Contributed papers, 12–22.

Saturday morning, December 21, 1940

9:30 o'clock: Contributed papers, 23–29, and invited paper on the 200-inch telescope by Dr. John A. Anderson.

# PROGRAM

## FRIDAY MORNING AT 9:30 O'CLOCK

**1. Measurement of the Absolute Yield of Gamma-Radiation.** J. F. STREIB, W. A. FOWLER AND C. C. LAURITSEN, *California Institute of Technology.*—The number of ion pairs produced per cubic centimeter of sensitive volume by radiation of unit flux (one quantum per cm²) falling on an electroscope completely surrounded by walls of solid material with $z<20$ has been computed for gamma-radiation extending from 2 to 25 Mev in energy. The calculations of Laurence and others have been extended to take into account the Compton effect, pair production, and the loss of energy by the secondaries through radiation and ionizing collisions. The results in ion pairs per cm³ per quantum per cm² are given below.

| WALL | $z$ | $h\nu$ (MEV) | | |
|---|---|---|---|---|
| | | 2 | 10 | 25 |
| Paraffin | 4.5 | 1.7 | 4.9 | 9.7 |
| Air equivalent | 7.2 | 1.8 | 5.7 | 12.1 |
| Aluminum | 13 | 1.9 | 7.1 | 16.5 |

Using these results we find the yield of the 6.3-Mev radiation from a thick $CaF_2$ target bombarded by protons with energy just above the resonance energy at 334 kev to be $1.8\times10^{-8}$ quanta per proton or $11\times10^{4}$ quanta per microcoulomb. This is in good agreement with the yield of $8.9\pm0.5\times10^{4}$ short range alpha-particles per microcoulomb found by Van Allen and Smith and confirms the belief that the quanta are emitted by an excited $O^{16}$ produced in the same reaction as the alphas. The thick target yield at 1.5 Mev is $2.2\times10^{-6}$ quanta/proton.

**2. The Photo-Disintegration of the Deuteron.** WILLIAM RARITA* AND JULIAN SCHWINGER, *University of California.*—High energy photo-disintegration experiments provide a fruitful source of information concerning the neutron-proton interaction in odd parity states. Fröhlich, Heitler and Kahn[1] have attempted to show that the strong spin-spin coupling of the mesotron theory has a predominant effect at high energies. Unfortunately, their calculation involves the use of inexact, singular wave functions. We have avoided this difficulty by employing a simplified potential which permits exact solutions for the pertinent states of the deuteron. The potential adopted was that following from a symmetrical mesotron theory:

$$V=\tfrac{1}{3}\boldsymbol{\tau}_1\cdot\boldsymbol{\tau}_2\{1+\gamma S_{12}\}J(r),\quad S_{12}=3\frac{\boldsymbol{\sigma}_1\cdot\mathbf{r}\boldsymbol{\sigma}_2\cdot\mathbf{r}}{r^2}-\boldsymbol{\sigma}_1\cdot\boldsymbol{\sigma}_2$$

with $J(r)$ assumed to be a rectangular well of range $r_0$ and depth $V_0$. $\gamma$ was chosen as constant, thus avoiding the singularities which arise in mesotron theory from a highly questionable application of perturbation theory. The constants $\gamma$ and $V_0$ were determined by the binding energy and quadripole moment of the deuteron assuming a range of $2.8\times10^{-13}$ cm. The cross sections and angular distributions for electric dipole, magnetic dipole and electric quadripole photo-disintegration were studied, employing the continuum wave functions deduced from this potential. The resultant photoelectric and photomagnetic cross sections for a $\gamma$-ray of 17.4 Mev are respectively equal to $0.77\times10^{-27}$ cm², and $0.95\times10^{-29}$ cm². The photoelectric cross section of Fröhlich *et al.* is $4.4\times10^{-27}$ cm². Similar calculations with a simplified neutral potential are in progress.

* On sabbatical leave from Brooklyn College, Brooklyn, N. Y.
[1] H. Fröhlich, W. Heitler and B. Kahn, Proc. Roy. Soc. **A174**, 85 (1940).

**3. Gamma-Rays from C+H².** T. W. BONNER, *Rice Institute,* R. A. BECKER, S. RUBIN AND J. F. STREIB, *California Institute of Technology.*—Tuve and Hafstad[1] reported a 2.7-Mev gamma-ray from carbon bombarded by 1.0-Mev deuterons and attributed[2] it to the reaction $C^{12}(d,p)C^{13*}$. Evidence for a weak gamma-ray of higher energy was also obtained. From energy balance considerations Bonner and Brubaker[3] attributed this gamma-ray to $C^{13}(d,n)N^{14*}$. However, the possibility that it could be caused by the radiative capture reaction $C^{12}(d,\gamma)N^{14*}$ could not be ruled out.[4] We have bombarded a target of ordinary carbon and also one enriched[5] in $C^{13}$ with 1.0-Mev deuterons. Measurements of secondaries ejected from a thin lead lamina by the radiation reveal a strong gamma-ray at $3.0\pm0.2$ Mev and one of approximately 5 percent relative intensity near 5.5 Mev from the ordinary target. Bombardment of the enriched target revealed a large increase in the relative intensity of the higher energy gamma-ray indicating that the original reaction assignments are correct. These results also indicate that the excited state of $N^{14}$ found by Lauritsen and Fowler[6] in the reaction $C^{13}(p,\gamma)N^{14*}$ is at 5.4 rather than 2.8 Mev.

[1] Tuve and Hafstad, Phys. Rev. **48**, 106 (1935).
[2] See also Bethe, Phys. Rev. **47**, 633 (1935).
[3] Bonner and Brubaker, Phys. Rev. **50**, 308 (1936).
[4] Bennett and Bonner, Phys. Rev. **58**, 183 (1940).
[5] Townes and Smythe, Phys. Rev. **56**, 1210 (1939).
[6] Lauritsen and Fowler, Phys. Rev. **58**, 193A (1940).

**4. A Magnetic Electron-Pair Spectrograph.** E. P. TOMLINSON, *California Institute of Technology.*—A magnetic beta-ray spectrograph has been modified for the purpose of measuring the energy of positive and negative electron pairs. Magnetic fields up to 2000 gauss can be produced across a $2\frac{1}{4}''$ gap between $6''\times18''$ rectangular pole pieces. An evacuated box between the pole pieces has an entrance window for pair members at the center of its top, a slit at each end of the top, and suitable baffles to define semi-circular paths of 9.5 cm radius between the entrance window and each slit. Geiger counters, one at each slit, are arranged to record coincidences between members of pairs in which the energy is equally divided between positive and negative electrons. The instrument is to be used for the

purpose of comparing the energy of pairs emitted from the $O^{16}$ nucleus produced by bombarding $F^{19}$ by protons with that of pairs ejected from lead by $\gamma$-rays from the same reaction.

**5. The Lifetimes and Ground States of $Be^{10}$ and $C^{10}$.** E. P. COOPER AND E. C. NELSON, *University of California.* (*Introduced by J. R. Oppenheimer.*)—The lifetimes, $\sim 10^6$ years and $\sim 10$ seconds, of the unstable isobars $Be^{10}$ and $C^{10}$ show that the transition $Be^{10}$ to $B^{10}$ is forbidden. Since the ground state of $B^{10}$ is a mixture of $^3S$ and $^3D$, the lifetimes might be explained by an assignment of $^1G$ to $Be^{10}$ and $^1S$ to $C^{10}$. However, using the single particle model with a symmetric Hamiltonian,[1] one finds the same order of levels in both $Be^{10}$ and $C^{10}$ with $^1S$ lowest. Since these two nuclei differ only by the exchange of two neutrons for two protons, this order might be altered by Coulomb forces, though we find from the symmetry of $Be^{10}$ and $C^{10}$ about $B^{10}$, the center of the $p$ shell, that the first-order contribution of the Coulomb energy[1] does not alter the order of the levels. We have made second-order perturbation calculations to see if it could make the needed level shift. In the Hartree approximation the separation $^1S-^1G$ is about 12 $mc^2$. The first- and second-order Coulomb energy shifts the levels so as to depress $^1G$ relative to $^1S$ but by not more than $0.3mc^2$, but the shift is a little more in $Be^{10}$ than in $C^{10}$. Hence the Coulomb energy could explain the ratio of half-lives, but only if the separation of the levels on the Hartree approximation is too large by a factor of order 10.

[1] E. Feenberg and M. Phillips, Phys. Rev. **51**, 597 (1937).

**6. An Interpretation of Fast Neutron Scattering.** STANLEY FRANKEL, *University of California.*—The angular distribution of fast neutrons elastically scattered by heavy nuclei, as reported by Kikuchi, Aoki and Wakatuki, shows a smooth rise with decreasing angle of scattering down to about 20° and then a sharp drop-off at the lowest measured angle, 14°. Theoretical distributions have been calculated from five approximate models. The experimental points were fitted by one of these, the Placzek-Bethe shadow-diffraction model, giving satisfactory agreement except for the point at 14° in each case. From consideration of the necessary degree of smoothness and of possible sources of error, it is concluded that this drop-off is probably spurious. This fitting determines rather sensitively an effective "radius" for neutron scattering. The "radii" so determined for seven elements, C, Al, Fe, Cu, Sn, Pb and Bi, are approximately linear in $A^{\frac{1}{3}}$, with one apparent exception, Cu. The linear relation best fitting them has a slope of $(1.25\pm0.10)\times10^{-13}$ cm and gives a "radius" of $(2.3\pm0.2)\times10^{-13}$ cm for $A=0$. These considerations would suggest the use of $R=1.3\times10^{-13}A^{\frac{1}{3}}$ cm for the nuclear radius, and for the elastic scattering distribution

$$\sigma(\theta)\cong R'^2(J_1(kR'\theta)/\theta)^2,$$

where $R=(2.3+1.25A^{\frac{1}{3}})\times10^{-13}$ cm.

**7. Excitation Energy of Excited $Li^7$.** S. RUBIN, *California Institute of Technology.*—A measurement of the excitation energy of the low lying excited state of $Li^7$ is being made by comparing the absorption coefficients in lead of the gamma-rays from the excited $Li^7$ produced by the reaction:[1]

$$Be^7+e_K^-\rightarrow Li^{7*}+\eta$$
$$Li^{7*}\rightarrow Li^7+h\nu$$

and the annihilation radiation from $N^{13}$ positrons. Beryllium carbonate obtained by chemical separation from a $Li^6$ target bombarded by deuterons[2] and sealed in a small glass capsule was used as a source of the $Li^7$ radiation. For the $N^{13}$ radiation, scrapings from the surface of a carbon target bombarded by deuterons will be placed in a small lead capsule, of sufficient wall thickness to annihilate all emitted positrons in the walls. These sources can be mounted in a standard position relative to a shielded, lead-lined, Lauritsen electroscope. A series of ten measurements at each of two absorber thicknesses gave an absorption coefficient of $1.635\pm0.015$ cm$^{-1}$ for the $Li^7$ gamma-ray. Using a coefficient of $1.51\pm0.05$ for the annihilation radiation as determined by Lauritsen and Fowler[3] under very similar geometrical conditions, the energy of $Li^7$ radiation is calculated to be $465\pm10$ kev.

[1] Roberts, Heydenburg and Locher, Phys. Rev. **53**, 1016 (1938).
[2] Prepared for us by Dr. S. K. Allison, University of Chicago.
[3] Fowler and Lauritsen, Phys. Rev. **56**, 841 (1939).

**8. The Theory of Cascade Showers in Heavy Elements.** H. C. CORBEN, *University of California.*—The one-dimensional equations of the cascade theory of showers are solved, account being taken of the Compton effect and of the variation with $\gamma$-ray energy of the cross section for pair production, as well, of course, as ionization and bremsstrahlung effects. These modifications are necessary for the discussion of cosmic-ray showers in elements of high atomic number, and the theory is developed in detail for lead. Introducing as usual the units $t$ of length and $\beta$ of energy, both characteristics of the material traversed ($t$, $\beta=240$ m, 90 Mev and 0.4 cm, 6.5 Mev for air and lead, respectively), one finds that the maximum number of particles $N_{\max}$ arising from an incident particle of energy $E_0=\epsilon\beta$ has in lead, for a given value of $\epsilon$, approximately three-quarters the value that it assumes in air. Thus, for lead, $N_{\max}\sim\epsilon/a$ where $a\sim11$ for $\epsilon\sim100$ and $a\sim13$ for $\epsilon\sim10^4$. For a given $\epsilon$, the maximum number of particles occurs at a distance (in units of $t$) slightly less for lead than for air, and for large distances the effect of the variation with energy of the pair-production cross section is to decrease the number of particles and increase the number of $\gamma$-rays to be expected.

**9. The Short Range Alpha-Particles from $F^{19}+H^1$.** R. A. BECKER, W. A. FOWLER AND C. C. LAURITSEN, *California Institute of Technology.*—A group of $\alpha$-particles of mean range about 8 mm was previously reported by this laboratory,[1] and by Burcham and Smith,[2] from the reaction $F^{19}(p,\alpha)O^{16*}$. These were found to show a resonance coinciding with that of the gamma-rays from $F^{19}+H^1$ at 334 kv. Energy considerations also indicated that they were associated with the gamma-rays. Subsequent measurements of Burcham and Devons[3] with an ionization chamber at the 334-kv resonance, and with magnetic analysis, at

the 660- and 862-kv gamma-ray resonances, showed the excitation function of the $\alpha$-particles to be identical to that of the gamma-radiation. It was also found that the $\alpha$-particles showed the same $Q$ at all three resonances. We[4] have confirmed these observations at 862 kv, and have extended them to the 927- and 1363-kv resonances, using a cloud chamber and employing magnetic analysis of the disintegration products. Within experimental error the $Q$ of the short range $\alpha$-particles at 862, 927 and 1363 kv was in each case found to be about 1.75 Mev, identical to that at 334 kv bombarding energy. This method of magnetic resolution is now being employed to study the short range $\alpha$-particles preceding the pair emission from $F^{19}+H^1$.

[1] McLean, Becker, Fowler and Lauritsen, Phys. Rev. **55**, 796 (1939).
[2] Burcham and Smith, Nature **143**, 795 (1939).
[3] Burcham and Devons, Proc. Roy. Soc. **173**, 555 (1939).
[4] Fowler and Lauritsen, Phys. Rev. **56**, 840 (1939).

**10. Electron Capture in White Dwarf Stars.** P. MORRISON, *University of California.* (*Introduced by J. R. Oppenheimer.*)—The spherical equilibrium distribution of a cold gas mixture of stripped nuclei and highly degenerate electrons is apparently a good model for white dwarf stars.[1] For great enough mass $M$ the Fermi pressure will not support the weight, and such a body will collapse. The limiting mass is given by Chandrasekhar as $M\mu^2<5.75\odot$, where $\mu$, the number of protonic masses per electron, is, for this completely ionized matter, equal to $2/1+X$, where $X$ is the mol fraction of protons in the mixture. There is another limiting value lower than this purely hydrostatic limit. When the free energy per electron exceeds some 800 kilovolts, protons will be unstable against electron capture. The central pressure reaches this critical value for $M\mu^2=4\odot$. For masses above this, protons will be unstable in the bulk of the star, and $\mu$ must be nearly 2. From the mass-radius relation we can find a radius $R=0.016R_\odot$ such that for $R\mu>R$ the body can contain hydrogen, for $R<R$ it certainly cannot. This seems consistent with the observed spectra of the white dwarfs of various radii. An unsuccessful attempt has been made to remove the radius discrepancy in Sirius B by constructing a model in which the outer layer contained $He^3$, which is unstable against electron capture when the free energy per electron reaches 20 kev. This model can account for the observed radius, even with $X=0$, but is, however, very unstable against mixing.

**11. Point-to-Plane Corona in Very Pure $N_2$ and $H_2$.** GERHARD L. WEISSLER, *University of California.* (*Introduced by Leonard B. Loeb.*)—These coronas were studied with a hemispherical 0.45 mm diameter Pt point at pressures of 760, 300 and 100 mm Hg. Earlier results reported for + point in $N_2$ and $H_2$* were found to have been falsified by minute traces of impurity. Positive points in pure gases gave no pre-corona-onset pulses at all. At corona-onset for the 3 pressures only a large number of minute single avalanche pulses were found with no streamers or burst pulses. Telemicroscopic observation revealed a corona spot of 0.1 mm diameter in distinction to the positive corona in air, which spreads uniformly all over the point. With increasing voltage the discharge extended visibly towards the cathode and before spark breakdown visible streamers appeared giving oscillographic kicks. They cross the gap without causing a spark, obviously being too feeble to create a hot-spot at the cathode. Streamers in $H_2$ before breakdown were even weaker than in $N_2$. The negative corona revealed at onset a glow which spread uniformly over the point, in distinction to the localized spot found in air. A few hundred volts above onset the current changed from $10^{-7}$ amp. to $10^{-4}$ amp. and the visible corona changed to a characteristic glow-discharge with cathode glow, Faraday darkspace and positive column. At higher potentials the discharge changed smoothly to an arc.

* Phys. Rev. **57**, 340 (1940).

## FRIDAY AFTERNOON AT 1:30 O'CLOCK

**12. An "Ultra-Spectrometer" Technique for Infra-Red Absorption Bands.** MARTIN SUMMERFIELD AND JOHN STRONG, *California Institute of Technology.*—The effect of total pressure on the infra-red absorption of ozone in the 9.6$\mu$ band was measured, extending the experiments of Strong and Watanabe.[1] Oxygen was the foreign gas used to control the total pressure. Measurements were made with a grating spectrometer of approximately 0.1$\mu$ resolution at 9.6$\mu$. The equivalent thickness of ozone in the cell was determined by absorption measurements in the Hartley band near 3100A. Curves are given showing the increase of absorption with pressure until saturation is reached. Further, in the neighborhood of the saturation pressure it is found that the transmission depends exponentially on thickness, while at very low pressures the absorption increases with square-root of the thickness. This is in accord with calculations of Elsasser.[2] By a quantitative study of this pressure effect based on the theory of collision broadening of spectral lines,[3] an estimate of the spacing of the lines in the band can be made. This opens the possibility of estimating the spacing of the rotational structure in bands of other heavy molecules with data obtained using spectrometers inadequate to resolve that structure. Not only bands but double lines or groups of lines may be similarly investigated to determine otherwise unresolvable details of structure. Calculations for the ozone band are described.

[1] Strong and Watanabe, Phys. Rev. **57**, 1049 (1940).
[2] Elsasser, Phys. Rev. **54**, 126 (1938).
[3] Margenau and Watson, Rev. Mod. Phys. **8**, 22 (1936).

**13. The Vacuum Spark Spectra of Cd IV and In V.** M. GREEN, *University of California.* (*Introduced by H. E. White.*)—The spectra of Cd IV and In V have been photographed in the region 300A to 1800A with a three-

meter normal incidence vacuum spectrograph. The irregular doublet law and the law of constant second difference has been applied in the classification of many of the lines of these two ions. The separation of the $4d^9\ ^2D$ multiplet of the ground state has been found for both ions. Most of the odd terms arising from $4d^85p$ and some of the even terms arising from $4d^85s$ have been determined. Some fifty transitions to the $4d^9\ ^2D$ levels have been classified for Cd IV and forty-two for In V. In cadmium IV some seventy-five lines have been classified as combinations between $4d^85s$ and $4d^85p$.

**14. Excitation of the Auroral Green Line in Nitrogen Afterglows.** JOSEPH KAPLAN AND SIDNEY M. RUBENS, *University of California.*—In 1928 Kaplan observed the auroral green line, λ5577, unaccompanied by other auroral radiations in the Lewis-Rayleigh afterglow, and later observed very large relative intensity of this line in weak auroral afterglows. Never before has the green line been recorded with an intensity sufficiently great to indicate that its emission is a primary radiative process in the afterglow as must be the case in the aurora. Not only has this now been accomplished, but 5577 is accompanied by the forbidden lines of oxygen λ2972, and of nitrogen λ3467 and the Vegard-Kaplan bands showing that the emission of forbidden radiations is a primary radiative process in these afterglows. In the present experiments the nitrogen was very pure, and a trace of pure oxygen was added. λ5577 increased in intensity with nitrogen concentration and exhibits the temporal effect of increasing in relative intensity with afterglow decay duration prior to its observation. This appears to be the most faithful reproduction of the auroral process ever achieved in the laboratory.

**15. On the Morphology of Nebulae.** F. ZWICKY, *California Institute of Technology.*—A study is presented of the structures of extragalactic nebulae. Particular emphasis is laid (a) on the distribution of mass and luminosity in nebulae, (b) on the dynamic characteristics of nebulae and (c) on the problem of the stellar content of nebulae. Those structural features which are subject to substantial changes in periods of time shorter than the lifetime of the average stars are subjected to an analysis utilizing the fundamental results of the hydrodynamics of laminar and turbulent motion supplemented through considerations based on statistical mechanics and on particle dynamics. A satisfactory understanding of the occurrence of globular, elliptical and irregular nebulae as well as of ordinary spirals and barred spirals may thus be arrived at. In addition, a number of the dynamic properties of nebulae are discussed. An attempt is also made to explain the differences in stellar content of various nebulae through a study of possible evolutionary sequences of stars and their relation to structural changes in nebulae.

**16. The Forbidden Lines of Pb I.** EDWARD GERJUOY, *University of California.*—Calculations have been made on the forbidden lines of the configuration $6p^2$ of Pb I and the results compared with experiment. Line intensities, hyperfine structure and Zeeman effect have all been investigated theoretically and experimentally. Some of the lines of this configuration, in particular $^1D_2-{}^3P_1$ (approximate Russell-Saunders labeling), permit simultaneous magnetic dipole and electric quadrupole radiation. This results in interference between these radiations in the various Zeeman components of experimentally observable magnitude. The interference vanishes after summing over all Zeeman components. The relative intensities of the Zeeman components depend only upon the quadrupole moment of the transition electron and are independent of the coupling. The agreement with experiment among the Zeeman components is good and self-consistent but requires the assumption of a smaller quadrupole moment for the transition electron than is indicated from the comparison of line intensities. An approximate calculation of the quadrupole moment of the transition electron is planned.

**17. Measurement of the Total Infra-Red Emission of Atmospheric Water Vapor.** WALTER M. ELSASSER, *California Institute of Technology.*—The thermal emission of columns of moist air was measured directly by the method of Hottel[1] which consists in screening off outside radiation by means of an extremely cold background. In our experiments the background was produced by means of a 30-inch searchlight mirror which was aluminized at the front side and at the focus of which a blackbody of liquid-air temperature was located. The receiving apparatus was a small reflecting telescope with a black disk and compensated thermocouple at the focus. Emissivities were measured for distances varying between 13 cm and 315 m corresponding to a range of moisture between $10^{-4}$ g/cm² and 0.3 g/cm². The known emission of carbon dioxide[1] in each path was subtracted. The water vapor emissivity was found to vary in the interval measured from 2 percent to 50 percent of the blackbody emission (air temperature 20°C). The solution of the problem of radiative heat transfer in the atmosphere has been worked out before;[2] our new results give corrections of 10–20 percent for numerical values previously used.

[1] H. C. Hottel and H. G. Mangelsdorf, Trans. Am. Inst. Chem. Eng. **31**, 517 (1935).
[2] W. M. Elsasser, Quar. J. Roy. Meteor. Soc. **66**, 41 (suppl. 1940).

**18. Design, Assembly and Preliminary Tests of a Curved Crystal γ-Ray Spectrometer.** W. K. H. PANOFSKY, J. W. M. DUMOND, R. Y. YOST, *California Institute of Technology,* AND H. A. KIRKPATRICK, *Occidental College.*—A curved-crystal γ-ray spectrometer has been constructed, using the (310) reflections of a quartz plate bent to a radius of curvature of 2 meters. The instrument covers the wave-length range from 500 x.u. to about 10 x.u., thus making accurate γ-ray wave-length measurements in the neighborhood of 1 Mev possible. The geometry of the instrument is such that either the source of radiation or the detector remain stationary when a wave-length setting is made; this is accomplished by moving the center of the focal circle simultaneously with rotating the crystal. For work at very short wave-length the beam reflected by the crystal planes diverges by only about ½° from the directly

transmitted beam; to make measurements at this wavelength possible, a collimator consisting of a set of wedge-shaped lead plates about 1 m long and spaced by similar spaces was constructed. Tests on the collimator showed that the intensity of radiation deviating 20′ from the desired beam was reduced to 1 percent. Constructional details of the instrument are given and the program of work contemplated is discussed.

**19. A Two-Stage Electron Microscope.** W. V. HOUSTON AND HUGH BRADNER, *California Institute of Technology.*—An electron microscope has been constructed in which the electrons transmitted by a thin film are brought to a focus in an image of the film. The electrons are emitted from a hot filament and accelerated by a potential difference of 40 kilovolts. The potential is produced by a rectifier and filter circuit and shows a ripple of about one volt. The electrons are focused upon the object by an electrostatic lens, and the transmitted electrons are focused into an enlarged image by two magnetic lenses of the type described by Ruska. Both the image formed by the first lens and the final image can be examined on fluorescent screens for the purpose of adjusting the focus. Magnifications up to 7000 diameters have been used, and it is thought that objects less than 300 angstroms in diameter can be distinguished.

**20. The Velocity of Propagation of the Electric Impulse Along the Organs of the Electric Eel.** W. A. ROSENBLITH, *University of California at Los Angeles,* AND RICHARD T. COX, *New York University.*—Observations previously reported[1] have shown that in the discharge of the electric organs of the electric eel a pulse of potential gradient runs along the organ from anterior to posterior. The speed of the pulse, roughly estimated, was found much higher than the highest speed recorded for impulses along nerves. Recently more accurate measurements have been attempted. Oscillographic traces of the discharge in two different segments of an electric organ were photographed and then plotted against each other with various assumed time-lags. This plotted figure was compared to the oscillographic trace obtained when the same two segments were connected respectively to the vertical and horizontal deflecting plates so as to give a loop picture corresponding to the true time lag. Though the margin of error may amount to as much as 20 percent it has been possible to confirm very definitely that the velocity of propagation of the discharge along the large organ ranges from several hundred to a thousand meters per sec. Hypotheses as to the possible nature of this velocity of propagation will be suggested.

[1] C. W. Coates, R. T. Cox and L. P. Granath, "The electric discharge of the electric eel, Electrophorus electricus," Zoologica **22** (Part 1), No. 1 (1937).

**21. The Deadtime of a Geiger Counter.** H. G. STEVER, *California Institute of Technology.* (*Introduced by W. H. Pickering.*)—The deadtime of a fast Geiger counter is the insensitive time measured from the initiation of one count till the counter is again sensitive. In the course of measurements on counter breakdown, an experiment to measure this deadtime directly was devised. The deadtime has been found to be a function of counter constants such as diameter, gas pressure and working voltage, but it does not depend on the external circuit. This deadtime for a counter of 1 inch diameter is of the order of $10^{-4}$ second.

**22. An Extremely Sensitive Biophysical Indicator for Metal Ions.** ALEXANDER GOETZ AND S. SCOTT GOETZ, *Cryogenic Laboratory, California Institute of Technology.*—The experimental conditions essential for using living cells as quantitative indicators for the presence of heavy metal ions (Ag, Au, Hg, Pb) have been worked out for Sacch. cerevisiae and $Ag^+$. As a prerequisite for the applicability of such methods, a staining technique developed whereby the cells affected by metal ions are differentiated from those not affected, renders it possible to obtain sufficient statistical material of cell mortality with microscopic counts. The study of the most efficient mixing technique for ions and cells as well as ways for avoiding wall adsorption of the ions resulted in this: Each cell can adsorb up to $10^9$ $Ag^+$; the value of $n/N \sim Ag^+/\text{cells}$ necessary to produce the stain reaction ($\nu$) is very small and approaches under the optimum temperature etc. conditions $\nu = 1$ when the Poisson probability:

$$\pi_\nu = \frac{x^\nu}{\nu!} \cdot e^{-x} \cdots (x = n/N) \cdots$$

is applied. This extreme sensitivity can be interpreted by assuming the living cell to act as a giant molecule in this reaction. A qualitative indication of the presence of a quantity of $10^{-8}$ g Ag is shown as lecture demonstration.

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## SATURDAY MORNING AT 9:30 O'CLOCK

**23. Preliminary Report on a Redetermination of $h/e$ by the Short Wave-Length Limit of the Continuous X-Ray Spectrum.** J. W. M. DUMOND, H. H. BAILEY, W. K. H. PANOFSKY AND A. E. S. GREEN, *California Institute of Technology.*—In order to shed new light on the apparent discrepancy of the natural atomic constants $h$, $e$, and $m$, a redetermination of $h/e$ by the short wave-length limit method is in progress, using the 30-kw Watters x-ray tube at this Institute. The large available intensity makes it possible to obtain intensity *vs.* voltage curves at constant wave-length for higher resolving power of the two-crystal monochromator than has hitherto been available, thus greatly reducing the "fillet" of the isochromats which appeared in past work. Improved methods of voltage stabilization and measurement were developed. Preliminary values of $h/e$ based on the measurements taken to date will be given.

**24. An Absolute Determination of the Continuous X-Ray Energy from Thin Aluminum Targets.** J. C. CLARK, *Michigan State College,* AND H. R. KELLY, *Stanford University.*—Ross's method of balanced foils has been used with foils of Cd and Ag to isolate a small region of the continuous x-ray spectrum from thin aluminum targets. The targets were made by the evaporation of aluminum upon a Cellophane supporting film. Preliminary measurements using target thicknesses 360A and 685A, at a distance of 34 cm from the x-ray source and azimuthal angle of 60°, give $J_v dv = 22.8 \pm 7.5 \times 10^{-36}$ erg per cm² per electron per second per atom per cm² of the target, when the energy of the bombarding electron is 31.7 kev. Sauter's wave mechanics theory[1] predicts $J_v dv = 1.27 \times 10^{-36}$ erg for the same bombarding electron energy and azimuthal angle. Scherzer's theory[2] predicts $1.22 \times 10^{-36}$ erg. Measurements of $J_v dv$ as a function of azimuthal angle compare very favorably with relative intensity measurements by Kulenkampff and Bohm.[3] Measurements are in progress to determine $J_v dv$ as a function of incident electron energy and atomic number of the target material.

[1] Sauter, Ann. d. Physik [5] **20**, 404 (1934).
[2] Scherzer, Ann. d. Physik [5] **13**, 137 (1932).
[3] Kulenkampff and Bohm, Ann. d. Physik [5] **33**, 315 (1938).

**25. A Theory of the Geneses of Primary X-Rays.** SAMUEL R. COOK, *Sacramento, California.*—Former theories of x-rays are briefly reviewed and it is shown that the existing theories are lacking in the presentation of a process of the geneses of primary x-rays. It is then suggested that a process of the genesis of a primary x-ray may be formulated by the consideration of the transformation of the electromagnetic field of force, associated with a cathode-ray electron, into the energy of a primary x-ray, during the collision of a cathode-ray electron with a nucleus of the anticathode material. It is then shown that by this suggested transformation an x-ray is generated, which conforms to the necessary requirements of a theory of the geneses and propagation of primary x-rays and fulfills the criteria both for interference and photoelectron emission and the quantum requirements both for emission and absorption. Mathematical formulations for the transformation of the electromagnetic energy associated with the cathode-ray electron into radiant energy of the newly generated x-ray are given. The general differential equations for the propagation of the x-ray quantum are derived and shown to be of the same general form as Maxwell's equations.

**26. Crystallization Phenomena, Crystal Structure and Fatigue in Metallic Conglomerates.** S. KYROPOULOS, *California Institute of Technology.*—In tensile strength tests on metallic conglomerates at ordinary temperatures, it is invariably in the crystallites themselves where rupture occurs, never in the crystal boundaries. With regard to impact fatigue, an important factor in bearing metal failure, it is generally stated that there is no connection between microstructure and fracture. The appearance of cracked Babbitt and lead bearings suggests, with due consideration of the crystallization process, that the cracks follow essentially the boundaries of the dendrites. Microscopic examination of a large number of cracks confirmed this: With two exceptions, where a brittle single crystal, subject to tensile stress, bridged two dendrites, the cracks were found to follow the dendrite boundaries. The thickness of brittle impurities or constituents, expelled at the boundaries, is the greater, the larger the dendrites, the diameters of which sometimes amount to 15 mm. The large dendrites, very nearly single crystals of high anisotropy with Sn and its solid solutions with Sb, tend to set up high elastic stresses under load or thermal expansion, which would partly account for the higher resistivity to cracking of isotropic metals like the cubic Pb.

**27. Burst Production by Mesotrons.** R. F. CHRISTY AND S. KUSAKA, *University of California.*—Making certain assumptions we have calculated the frequency of burst production as a function of burst size. For the mesotron of spin 1 and moment $e\hbar/2\mu c$, we have used the previously calculated knock-on formulae, supplemented by our own calculations of the bremsstrahlung: for the latter, the cross section has terms, significant for our work, in $E$, $\ln^2 E$, and $\ln E$. The *minimum* cross sections we used differ little from those given directly by the Born approximation. Using these cross sections, the cascade theory of showers, and a modified form of the Furry model to take into account the fluctuations, the frequency of burst production was calculated. The sea-level data of Schein and Gill[1] give for the number of bursts of size greater than $S$, $N_S \sim S^{-\gamma}$, with $\gamma \sim 1{\cdot}8$. Our calculations give for spin 1, $\gamma \sim 1{\cdot}5$ and numerically too many by a factor of 6. Similar calculations for the mesotron of spin 0 give $\gamma \sim 1{\cdot}8$ and the same in number as the observations within an uncertainty of about a factor $1{\cdot}5$. For spin $\frac{1}{2}$ and moment $e\hbar/2\mu c$, the bursts are approximately twice as numerous as for spin 0. This evidence thus favors spin 0, or possibly spin $\frac{1}{2}$, but tends to exclude spin 1.

[1] M. Schein and P. S. Gill, Rev. Mod. Phys. 11, 267 (1939).

**28. A New Circuit for Generating Alternating Electric Pulses of Very Short Duration.** G. POTAPENKO, *California Institute of Technology.*—A new generator of alternating electric pulses of short duration has been worked out. The generator uses gaseous triodes with an alternating potential supplied to their plates. The discharge through the tubes starts and stops automatically without requiring any relays or contacts to open or close the circuit. The starting of the discharge is controlled by the phase-shift between the grid and tube potentials. The stopping of the discharge and, therefore, the duration of it is controlled by the charging time of a condenser in the plate circuit of tubes. The frequency of current supplied to the tubes determines the number of pulses per second. The duration of pulses and their intensity can be controlled independently one from the other. With usual commercial tubes of 885-type the generator delivers pulses up to about 250–300 v peak value and down to about 0.0001 sec. in duration.

**29. The Value of the Rydberg Constant.** RAYMOND T. BIRGE, *University of California.*—From frequency measurements of the fine structure of H, D and $He^+$ lines, one can calculate the value of $R_\infty$ and of $\alpha$ (the fine structure constant). With an assumed value of the Faraday, one can also calculate $e/m$. A systematic recalculation has been made of all work in this field during the past 15 years. The present most reliable values of all auxiliary constants (*including* the index of refraction of air) have been used, and several small errors, some theoretical and some arithmetic, have been found and corrected. Because of time limitations, only the values of $R$ are here reported. From the observational data of DRW[1] alone, assuming only the atomic masses of H and D, and with some allowance for systematic errors, $R_H = 109{,}677.5810 \pm 0.0075$ cm$^{-1}$, $R_D = 109{,}707.4192 \pm 0.0075$, yielding $R_{He} = 109{,}722.264 \pm 0.012$ and $R_\infty = 109{,}737.303 \pm 0.017$, all in the I.A. system. A similar recalculation of Houston's data[2] gives $R_H = 109{,}677.680$ and $R_{He} = 109{,}722.296$, yielding $R_\infty = 109{,}737.312$. Chu's data[3] similarly give $R_{He} = 109{,}722.343$ which, combined with Houston's $R_H$, gives $R_\infty = 109{,}737.376$. The DRW data are the most reliable and I *adopt* $R_\infty = 109{,}737.30 \pm 0.05$ cm$^{-1}$, in the c.g.s. system.

[1] Drinkwater, Richardson and Williams, Proc. Roy. Soc. **A174**, 164 (1940).
[2] W. V. Houston, Phys. Rev. **30**, 608 (1927).
[3] D. Y. Chu, Phys. Rev. **55**, 175 (1939).

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***Invited paper on the 200-inch telescope***

JOHN A. ANDERSON, *California Institute of Technology, Pasadena, California.* (40 minutes.)

## SUPPLEMENTARY PROGRAM

**30. Neutron Stars as Gravitational Lenses.** F. ZWICKY, *California Institute of Technology.*—Collapsed neutron stars are so small that light passing near them is deflected through great angles. For a neutron star of mass $M$, at the distance $D$ this leads to the following conclusions. Any star at a distance $D' \gg D$ in the line of sight of the neutron star will produce a ring-like image of the diameter $\alpha = 4(\Gamma M/Dc^2)^{\frac{1}{2}}$ where $\Gamma$ and $c$ are the gravitational constant and the velocity of light. *Every* other star will produce one only slightly deflected direct image and one strongly deflected image which lies within the ring $\alpha$. Within this ring, therefore, appears a *miniature edition* of *all of the unobscured luminous objects* in the universe. If $D$ is small enough, or if the neutron star is favorably located, the miniature image may be observable. The spectrum of the miniature image is a composite weighted spectrum of many stars. If the neutron star theory of supernovae is correct, the number of collapsed stellar remnants of supernovae in our galaxy should exceed one million and several collapsed neutron stars may be expected within a sphere of ten light years. A search for miniature images of the universe produced by neutron stars in our neighborhood is suggested.

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